

Semi-ANNUAL Review of Research and Advanced
Development, Vol I: 71-III, 1968
PLANETARY QUARANTINE (186-58)

INERTIAL SENSOR STERILIZATION

NASA Work Unit 186-58-02-03-55

JPL 384-82701-2-3440 ✓

P. J. Hand
(Jan-June, 1968)

OBJECTIVE

The objective of this work unit is to perform in-house evaluation of the performance and thermal sterilization capabilities of the newest designs of miniature inertial sensors. Additionally, the ability of these instruments to withstand the spaceflight and launch environments of vibration and shock is also being evaluated. This work unit is primarily a housekeeping task covering the necessary JPL manpower, test equipment maintenance, and environmental test facility use required to perform the evaluation of these instrument designs.

STATUS

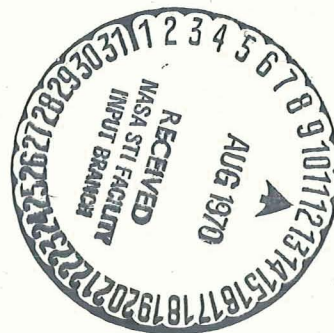
At this time, the long-term performance and environmental capability are being assessed on the Kearfott Alpha III gyro design, and thermal sterilization capabilities of the Bell Model VII accelerometer are being evaluated. Progress on each of these tasks is reported under work unit numbers 186-68-02-30-55 and 186-58-02-09-55.

PUBLICATIONS

None.

FACILITY FORM 602

N70-75934	(THRU)
(ACCESSION NUMBER)	
36	(CODE)
(PAGES)	
CR-112827	(CATEGORY)
(NASA CR OR TMX OR AD NUMBER)	



STERILIZABLE GAS BEARING GYRO DEVELOPMENT

NASA Work Unit 186-58-02-07-55

JPL 384-81101-2-3440

P. J. Hand

OBJECTIVE

The objective of this work unit is to develop the Honeywell, Inc., type DGG159 single-axis, gas-bearing gyroscope into an instrument capable of surviving a thermal sterilization environment of 135°C without either failure or significant performance degradation.

STATUS

Work has been progressing at Honeywell, Inc., on the fabrication of the DGG159E model of this gyro design. The E model gyro will draw together all the improvements developed by JPL funding since 1963. These improvements include a low-power spin motor with support bearings capable of 200-g shock levels, thermal sterilization capability, and a high-frequency gimbal suspension pump.

The problems associated with moisture contamination of the spin motor gas bearing, discussed in the last report (R&AD Program Document 701-6, Vol. I), have been corrected. The design of the gas pumping grooves on the journal bearing was changed to permit a gas flow-through condition within the bearing. The flow-through design will be capable of carrying away moisture faster than it can condense. The original bearing was deliberately designed to have a high gas pressure at the center of the journal bearing and no gas was allowed to flow through the bearing. This approach saved some power, but was determined to be sensitive to microscopic amounts of condensed liquid water.

The flow-through design, coupled with 300°F vacuum bake out of all gimbal and motor parts, has effectively solved the motor hang-up problem without sacrificing either of the original design goals of high shock capability or low motor power requirements.

An encapsulation technique using a metallic can was also developed for the motor stator windings to reduce the possibility of particulate contamination entering the bearing from this source.

Methods of identifying both particulate and gaseous contamination within the gimbal have been developed by Honeywell using advanced methods of infrared analysis, ultraviolet fluorescence, mass spectroscopy, gas chromatography, and hot-stage microscopy.

The DGG159E is not in the final stages of assembly. Testing at Honeywell will proceed on a schedule that will allow delivery of the gyro to JPL in September 1968. JPL will then conduct an evaluation to verify the sterilization capability and long term performance.

PUBLICATIONS

SPS Contributions

1. Hand, P. J., "Sterilizable Inertial Sensors (Type DGG159E and DGG334S Gyros)," SPS 37-51, Vol. III, May 1968.

Contractor Reports, Interim and Final

1. Erickson, C. J., "The Design and Build of a Gas Bearing Gyroscope Possessing High G and Sterilization Capability and Utilizing a Low Power Spinmotor and High Frequency Pump," Honeywell, Inc., Fifth Quarterly Progress Report No. 20660 QR5, JPL Contract 951559, Jan. 1, 1968 to Mar. 31, 1968.

STERILIZABLE SUBMINIATURE GYRO MOTOR EVALUATION

NASA Work Unit 186-58-02-08-55

JPL 384-81201-2-3440

P. J. Hand

OBJECTIVE

The objective of this work unit is to evaluate the thermal sterilization capabilities of one of the newest forms of subminiature ball bearing gyro motors. This task is corollary to task 186-68-02-30-55 in that the motor used is the same as the motor in the Alpha III gyro being evaluated under that work unit number.

STATUS

The 2-yr development contract (952019) placed with Kearfott, Inc., has been proceeding without major difficulty. This contract is divided into two phases.

The first phase deals with the heat sterilization of motor piece-parts and subassemblies at 135°C, for a total of 6 cycles at 70 hr each. This phase will detect any adverse temperature effects at the subassembly level that might be overlooked on the completed motor. During the second phase, two motor assemblies are built up and sterilized at the same conditions as the piece-parts. After each sterilization cycle, the motors are placed on test to see if performance is affected. Life tests are scheduled for both motor assemblies, provided they survive the sterilization environment.

The first phase has been completed without encountering any problems. One significant fact discovered, which was also noted on other sterilization development programs, was that certain of the epoxy adhesives used in assembling the gyro motor actually became stronger after the six sterilization cycles. This indicates that some of the recommended cure cycles may not be long enough.

The second phase has progressed through the point of motor assembly and first sterilization cycle. Prior to motor assembly, the four spin motor bearings used in the assembly were selected from a quantity of eight. This selection was based on a 40X visual inspection. The bearings were processed following standard procedures and impregnated with SR-60 lubricant. The gyro motors were assembled and run-in following standard procedures, with the exception of an increased number of bearing visuals and power input tests. The motors were installed into the sterilization containers and hermetically sealed. To correct a header deficiency, one container was disassembled and recycled. The containers were then filled with one-quarter atmosphere of helium and run-in testing was started. The containers were immersed in an oil bath during run-in testing and the fluid temperature maintained at 115°F. One motor was run an additional 145 hr for a total run-in time (motor and container) of 331 hr before the first sterilization reference. Similarly, the other motor was run an additional 156 hr for a total run-in time of 342 hr. Motor performance and power inputs were checked at intervals during and after completion of the run-in test. These data will serve as a pre-sterilization reference.

After completion of the run-in test, the containers were removed and delivered to the environmental laboratory, where the heat sterilization was performed. After the first sterilization, and prior to power turn-on, the containers were leak-checked to ensure the integrity of the hermetic seal, and motor resistance was checked. The motor performance of each unit was checked, and the power input was monitored on each for the first 30 min of run-in. Each unit was run for 102 hr, during which motor performance and power were checked at regular intervals. The motor characteristics and power input performance were very good throughout the run-in period, with only minor changes in run-down time occurring.

The results indicate that the two gyro motors have successfully passed the first sterilization cycle. From the data, it appears that none of the motor characteristics were affected by the sterilization cycle. It is evident at this point in the program that the ALPHA III gyro motor can safely withstand at least one sterilization cycle. When the motors pass all 6 cycles, they will be

subjected to a life test of at least 2000 hr as a check for possible long-term wearout conditions that may have been brought on by the 135°C exposure.

PUBLICATIONS

Contractor Reports, Interim and Final

1. Brophy, T., "C702543 Alpha III Ball Bearing Gyroscope Motor Sterilization Program," Kearfott Inc., Report No. B194000216, May 15, 1968, JPL Contract 952019.

DEVELOPMENT OF A STERILIZABLE HIGH- PERFORMANCE ACCELEROMETER

NASA Work Unit 186-58-02-09-55

JPL 384-81301-2-3440

P. J. Hand

OBJECTIVE

The objective of this work unit is to develop thermal and gas sterilization capability into a new design of miniature high-performance accelerometer. This would make available a versatile force balance instrument which is capable of either digital- or analog-type of operation. System designers could then make use of this device in planetary orbiters, entry systems, or landed devices as well as for midcourse and terminal velocity control of Mariner-class spacecraft.

The accelerometer chosen for this development is the Bell Aerosystems Model VII. This is the same basic instrument used on the Apollo Lunar Module abort guidance system.

STATUS

A modification to the original contract with Bell Aerosystem has been agreed upon, and work was resumed on the Phase One Program in February 1968 after a 5-mo delay. The basic change was to remove the actual sterilization cycling and testing from the contract with Bell and perform these operations at JPL. In this manner the final amount of the contract overrun was reduced to \$8,830, which was within the limits of available funds.

A follow-on Phase Two Program has been negotiated with Bell, and the contract should be released before the fiscal year closes. This Phase Two effort will involve four more instruments, experiments with advanced fabrication techniques and an advanced pickoff preamplifier design which would eliminate coupling transformers.

The first version of the sterilizable Model VII accelerometer was delivered to JPL in May. This instrument utilizes all materials and methods developed during the first phase of the contract. Principally a stronger and higher temperature adhesive is used in the proof mass assembly and a more stable design of pick-off preamplifier was incorporated.

During the first 20 days of stability testing at JPL the performance of this unit (SN 656) has been very satisfactory. Ten heat cycles have been performed from room temperature to 165°F with bias and scale factor measured before, after, and during the temperature run. At the controlled temperature of 165°F, the instrument has demonstrated a bias stability (1 sigma) of $7.6 \mu \text{ g}$. At room temperature the bias stability is $35 \mu \text{ g}$, however this includes the effect of the shifts caused by the temperature cycling.

Scale factor has also been satisfactory, demonstrating a 1-sigma stability of $56 \mu \text{ g}$ at the controlled temperature.

Additional testing will include $\pm 1 \text{ g}$ linearity, pick-off scale factor and flexure restraint measurements. After the unit has received 20 heat cycles and more than 30 days have elapsed, sterilization testing will begin. At least 6 cycles of 60 hr each will be performed at 135°C with stability testing taking place before and after each cycle. If the instrument survives the sterilization series, additional environmental testing such as shock and vibration will be scheduled.

PUBLICATIONS

None.

STERILIZABLE SCIENCE DATA BUFFER

NASA Work Unit 186-58-03-02-55

JPL 384-84701-2-3240

P. B. Whitehead

OBJECTIVE

The objective of this work unit is to gain understanding of the design and manufacture of a sterilizable memory for use in future flight projects.

ACCOMPLISHMENTS

During February, General Precision Inc., Librascope Group, delivered to JPL two woven plated wire memory stacks. One of these stacks was mated to breadboard electronics at JPL and became the memory for the entry data system (EDS) of the capsule system advanced development (CSAD). The memory has operated for about 3 mo without failure as part of the EDS. During the last 2 mo the EDS has been included as part of the CSAD system test at SAF.

The other stack is to be used for environmental testing. In preparation for this testing, equipment has been ordered to duplicate the test setup used by Librascope to evaluate the stacks. The equipment includes a programmable pulse generator and two current pulse generators.

FUTURE ACTIVITIES

The sterilization requirements and other environmental specifications developed for CSAD are being compared with similar specifications for Mariner Mars 1969, 1971 and 1973 in order to develop a set of meaningful tests for the second stack. In general, the tests will involve sterilization, shock, and vibration.

Tests will be run on the breadboard memory to determine its temperature margins and its ability to operate under vibration. A high temperature life test will be conducted with the memory operating at its fastest rate.

PUBLICATIONS

None.

SENSOR STERILIZATION AND TEST PROGRAM

NASA Work Unit 186-58-06-02-55

JPL 384-84601-2-3220

R. A. Wengert

OBJECTIVE

The purpose of this program is to develop sterilizable sensors which are unique to scientific instrumentation, and to conduct an evaluation program to prove the sensors worthy for use on planetary entry and landed missions. The units being studied are:

- (1) GM counter tubes
- (2) Solid-state radiation detectors
- (3) Photomultiplier tubes
- (4) Inorganic scintillation crystals
- (5) An optical detector-scintillation crystal assembly

PROGRESS

G.M. Counter Tubes

The development effort has been completed and units produced according to the resulting specifications are being evaluated in the test portion of the program.

Solid-State Radiation Detectors

All necessary development effort has been completed and, as a result, the state of the art has progressed to the point of meeting the requirements.

Photomultiplier Tubes

The contractor has completed the development effort for this task. Although a change in the value of the quantum efficiency is experienced as a

result of heat sterilization, analysis of the test data indicates that the change can be quite accurately predicted. The energy resolutions of the tubes remain very stable. The contract final report is now being prepared and it is anticipated that it will be received by June 30, 1968.

Inorganic Scintillation Crystals

The development effort has been completed and it is expected that the final report will be received by June 30, 1968.

Optical Detector-Scintillation Crystal Assembly

The development effort has been completed and the final report is expected to be received by June 30, 1968.

Test and Evaluation Program

The G. M. counter tubes and solid-state radiation detectors were subjected to a final cycle of heat sterilization on April 25, 1968. The units have been under test since that time with very favorable results. Although this task will be terminated at the end of FY 68, the automated test stations will permit some additional testing to be performed and better statistical information to be made available.

At the close of FY 68, the inorganic scintillation crystals and photomultiplier tubes will not have been tested beyond that effort performed by the development contractors. Such a program should be undertaken in the future.

PUBLICATIONS

None.

STERILIZED SOLID ROCKET TECHNOLOGY DEVELOPMENT

NASA Work Unit 186-58-08-01-55

JPL 384-81901-2-3810

S. N. Prescott

ELECTROEXPLOSIVE DEVICE STERILIZATION

OBJECTIVE

The feasibility of thermally sterilizing electroexplosive squibs and devices for use in planetary exploration spacecraft is being investigated by tests with present state-of-the-art hardware items.

STATUS

Squibs from four manufacturers and two types of electroexplosive devices have been exposed to repeated thermal sterilization cycles and functionally tested. The test results were compared with the results of tests on squibs and devices which were not thermally preconditioned. Samples of the electroexplosive devices used in the CSAD feasibility model were exposed to 2500 g shock pulses and then actuated to demonstrate their ability to withstand the impact of a planetary landing.

TEST ARTICLES

The following squibs and devices were tested during this report period:

Atlas IGN-141 squib	Candidate for Mariner Mars 1969 pin-puller
Space Ordnance System ASI squib	Candidate for Mariner Mars 1969 pin-puller
Hi-shear PC-42-005 squib	Surveyor pressure valve squib
Holex 5700 squib	Igniter squib (additional igniter tests are covered in separate report)

Atlas IMT-90 pin-pusher

Developed for JPL CSAD boom
release

JPL 10024212 bolt cutter

Developed by JPL for CSAD
parachute release (uses Hi-shear
PC42-005 squib)

STERILIZATION METHOD

The squibs and devices were exposed to from one to six sterilization cycles. Each cycle consisted of a 56-hr soak at 275°F (135°C).

TEST METHODS

Each squib was installed in a closed pressure bomb with a crystal-type pressure transducer. A constant direct current pulse was applied to the bridgewire of the squib. Current and output pressure versus time were recorded on an oscilloscope camera.

Each JPL-developed bolt cutter was assembled with an 0.190-dia, 180,000-psi bolt, and its squib was fired with a dc pulse.

Each pin-pusher was installed on a ramp. It was actuated with a dc pulse and the pin propelled a steel ball up the ramp. The current-time and the time interval for the ball to pass two electrical contacts on the ramp were recorded on an oscilloscope camera.

Bolt cutters and pin-pushers were exposed to 2500 g shock pulses of 1.25 ms duration and then actuated as described above.

ANALYSIS OF DATA

The squib firing sensitivity, as determined by the firing delay at constant current, was compared on sterilized and unsterilized squibs and at several levels of firing current.

The squib output pressure was compared on sterilized and unsterilized samples.

The output energy of the pin-pusher, as indicated by the velocity of the steel ball, was compared with the energy from unsterilized pin-pushers.

The bolt cutter function was evident from the separation of the 0.190-dia bolt.

CONCLUSIONS

The Atlas IGN-141 squib is not suitable for thermal sterilization. The other squibs and devices were not affected by exposure to 275°F (135°C). The pin-pusher and bolt cutter will operate satisfactorily after exposure to 2500 g shock.

PUBLICATIONS

None.

STERILIZABLE PYROTECHNIC SUBSYSTEM DESIGN, W. S. Wuest

OBJECTIVE

The objective of this work was to verify the sterilizability of the capacitor discharge squib-firing circuit. The effort was organized as a subsystem of the capsule system advanced development (CSAD) program. One set of flight hardware and one set of operational support equipment were fabricated, and support was lent to the capsule design and systems test.

STATUS

The program is now complete. All objectives were successfully accomplished. The pyrotechnic subsystem was subjected to the prescribed sterilization cycle as a component of the CSAD feasibility model and subsequently passed its operating criteria in conjunction with the capsule system.

The pyrotechnic subsystem was capable of redundantly executing five pyrotechnic events: capsule separation, spin-up, deflection motor ignition, despin, and maneuver package separation. The firing unit weighed 3.16 lb. It was part of the maneuver package, hence was jettisoned and did not contribute to the entry weight of the capsule.

The capacitor discharge type of squib-firing circuit was utilized. This permits the number of squibs which are fired simultaneously to be independent of the current capability of the spacecraft battery. The circuit which was used was substantially the same as the Mariner Mars 1969 squib-firing circuit. The CSAD unit was capable of firing four squibs simultaneously. It also fulfilled the requirement to fire two events simultaneously — capsule separation and spin-up. All squibs were of the 1A/1W type. However, due to the energy storage concept, the maximum current required from the battery was less than 30 ma.

A rack of operational support equipment (OSE) was fabricated to test the subsystem both as a component and as a part of the capsule system. The OSE also incorporated provisions for testing a squib-firing circuit which was provided by others and located in the CSAD lander.

PUBLICATIONS

None.

STERILIZABLE SOLID ROCKET TECHNOLOGY, W. L. Dowler

OBJECTIVE

The objective of this task is to demonstrate feasibility and solve the engineering problems involved in sterilizable solid propellant motors.

STATUS

Because of reduced funding levels, work on sterilizable solid propellant motors was continued at a very low level; thus, significant results have not been obtained.

PLANNED ACTIVITIES

Work toward the 60-lb sterilizable motor feasibility demonstration is planned to continue during the next 6 mo.

PUBLICATIONS

None

STERILIZABLE LIQUID PROPULSION SYSTEM DEVELOPMENT

NASA Work Unit 186-58-08-02-55

JPL 384-82101-2-3840

M. E. Guenther

OBJECTIVE

The objective of this work unit is to develop the technology required for the use of sealed, ethylene oxide-compatible, heat-sterilizable liquid propulsion systems. Such systems will be required for probes or capsules that enter planetary atmospheres. The liquid supply system technology will also have application as a monopropellant supply system for a turboalternator auxiliary power unit driven by gaseous products for hydrazine decomposition.

STATUS

The bipropellant work is being handled primarily by an industry contractor. The contractor has conducted a design and experimental investigation, and has performed a feasibility demonstration of a sterilizable liquid bipropellant propulsion system. To conduct this program, the contractor designed an integrated, modular bipropellant system, procured the required component parts, and assembled the components into a complete system module. The system module was subjected to ethylene oxide exposure. Thermal cycling of the system module was completed and a successful demonstration firing of the sterilized system was conducted January 16, 1968. Post test inspections revealed areas of degradation in individual components but probably not drastic enough to cause a test failure. However, these problem areas detract from a high confidence level and plans were made to correct them and to repeat the demonstration firing. More extensive compatibility testing of materials was also a decided requirement. To accomplish these two tasks, a supplement to the existing (951709) contract was initiated and should be executed approximately July 8, 1968. The supplemental effort valued at approximately \$95000 will cover nearly 6 mo effort in time; \$45000 is being funded from the existing

FY 68 funds and approximately \$50000 incrementally from FY 69 funds. A draft of the final report covering the initial contract effort has been submitted.

A secondary (back-up) effort was initiated in-house for FY 68. This in-house effort is in the form of a prototype monopropellant system capable of withstanding the sterilization environment without appreciable degradation of performance when test fired. The preliminary prototype system was defined. Procurement of all components except for the propellant expulsion tank assembly was initiated. The monopropellant system will utilize components developed from existing in-house efforts and the Martin-Denver contract. Technological information gained from the Martin-Denver contract, as well as in-house information, will be fully utilized in the final design and assembly of a system module. The final design and component procurement is expected to be completed during the first half of FY 69. Assembly of the monopropellant system, sterilization cycling, and a demonstration firing are scheduled for completion by the end of FY 69.

PUBLICATIONS

Contractor Reports, Interim and Final

1. Lukens, S., Project Manager, Martin Corp., Denver Division. AIAA 4th Propulsion Joint Specialist Conference, JPL Contract 951709, June 10-14, 1968.
2. Lukens, S., Quarterly Contract Reports, Martin-Marietta Corp., Denver Division. Nos. MCR-67-15, First, Second, Third, Fourth, Fifth Issue, JPL Contract 951709.
3. Brady, H. F., and Di Stefano, D., Final Report, Martin-Marietta Corp., Denver Division, MCR-68-119.

STERILIZABLE POLYMERS
NASA Work Unit 186-58-13-02-55
JPL 384-83801-2-3510
W. D. Roper

OBJECTIVES

The long-range objective of this work unit is to establish a comprehensive list of polymeric products suitable for spacecraft applications which can withstand ethylene oxide decontamination and thermal sterilization. As an expansion of previous studies, the FY 68 work has included the study of the effects of an additional environment: long-term (500 hr) thermal-vacuum exposure (135°C , 10^{-6} torr) which can be considered as simulating a spacecraft environment.

PROGRESS

During the last half of FY 68 the polymeric materials studies conducted at the Autonetics Division of North American Rockwell Corp., and which were originated from FY 67 funding, were completed with the issuance of a final summary report. These studies evaluated the compatibility of some 180 materials to exposure to ethylene oxide, plus thermal sterilization cycles according to JPL Spec VOL-50503-ETS. The polymeric products were selected from 20 different material categories such as adhesives, sealants, laminates, etc. After each material was given the decontamination and sterilization treatments, physical, mechanical, and electrical property changes were assessed and compatibility ratings based on these changes were assigned to each material.

Of the total number of materials investigated, approximately 50% could be classed as compatible to ETO plus thermal sterilization; 23% were rated marginal and the balance, 27% were found noncompatible. In addition to the establishment of the good space grade materials, it is of equal importance that the noncompatible materials have been determined and can now be eliminated from any further consideration as spacecraft materials.

During this same FY 68 period the polymeric materials studies being conducted within the JPL materials section, and which are an extension of the Autonetics and previous work, have been continuing. In this program approximately 25 materials are being evaluated for compatibility, not only to ETO and thermal sterilization cycles, but also to a thermal vacuum exposure of 500 hr at 135°C and 10^{-6} torr. This latter environment is a simulated spacecraft environment.

During this last period, this materials investigation has progressed to an over-all program completion of approximately 70%. Program planning, sample procurement and preparation, and ETO exposure are essentially complete. Thermal sterilization has also progressed to 60% completion. During this same period, contractual agreement was made with Stanford Research Institute for their thermal-vacuum exposure work of this program. This latter exposure work is 25% completed.

In addition to the materials studies within the materials section, it was also planned in FY 68 to develop within the Materials Testing Laboratory, an ETO sterilization apparatus. During the last period a thorough review of the commercially available equipment and an appraisal of various vendor bids were made. An equipment source selection was ultimately completed. The equipment has been ordered and delivery and installation is anticipated during the first half of FY 69.

FUTURE PLANS

It is projected that the present polymeric materials studies will be completed within the first half of FY 69. In addition to these activities, the FY 69 objectives under this work unit will also include (1) the investigation of the interactions of several materials exposed simultaneously to the various sterilization and simulated spacecraft environments, and (2) the completion of the development of the ETO exposure facility. Some continued effort in the expansion of the qualified polymeric materials list is also anticipated.

PUBLICATIONS

Contractor Reports, Interim and Final

1. Lee, S. M., and Licari, J. J., "Effects of Decontamination and Sterilization on Spacecraft Polymeric Materials," Autonetics Division of North American Rockwell Corp., Final Report, JPL Contract 951566, Jan. 12, 1968.

STERILIZABLE ELECTRONIC EQUIPMENT PROCESSES

NASA Work Unit 186-58-13-03-55

JPL 384-85301-x-3570

R. F. Holtze

OBJECTIVE

The long-range objective of this work unit is to develop and qualify sterilizable material applications and processes for assembling and packaging of electronic equipment. The present effort will attempt to determine the effect sterilization has on physical or chemical interaction between embedment materials and components that would affect the functional use of such subassemblies.

BACKGROUND

Previous results have indicated that embedment compounds did affect the functional parameters of certain components embedded in them, as a result of the sterilization cycles. The test data indicated that embedment compounds exert a definite pressure on embedded components with the pressure increasing as a result of sterilization. When measured at room ambient temperature, the pressure exerted by a typical syntactic foam increases from 1200 to 1900 psi after having been subjected to sterilization conditions. This increased pressure has an effect on certain parameters of components, notably the resistors and capacitors. The present work is designed to evaluate sterilization effects on additional embedment materials and the effect that these sterilized materials have on the parameters of certain selected components.

ACCOMPLISHMENTS

A total of 12 different components was tested. These components were selected from the sterilizable component list issued by JPL and include five resistors of various types, three different capacitors, two types of inductors, one diode, and one thermistor. All components have been procured, burned-in at 275°F, screened for operating characteristics and fabricated into typical

cordwood-type modules. A total of 20 parts of each of the 12 different types was embedded in each of the 5 material systems being tested. A control system containing unembedded components was also included. Figures 1 and 2 illustrate typical modules, both before and after embedment.

All modules have been embedded and tested. Four different embedment materials were used. Processing difficulties were encountered with a fifth material, and schedule limitations forced discontinuance of this material. The four materials being tested were (1) Stycast 1090 from Emerson and Cumming Corp., meeting MSFC Specification 222B-Type IV; (2) Scotchcast 5090, Minnesota Mining and Manufacturing Co.; (3) Scotchcast 281, Minnesota Mining and Manufacturing Co.; (4) Stycast 2850 FT from Emerson and Cumming Corp., meeting MSFC Specification 222B-Type III.

Operating parameters of each component in the embedded and control (unembedded) modules have been determined after each of the following manufacturing or environmental test procedures:

- (1) Fabrication into cordwood-type modules
- (2) Embedment using selected materials
- (3) Exposure to both ETO and thermal sterilization conditions
- (4) Exposure to low temperature (-35° F)

In addition to the embedded component modules, test work was also done to determine the actual pressure that the different embedment materials did exert. This determination was made using the thermometer embedment method and also by means of pressure-calibrated carbon composition resistors incorporated in the cordwood modules. Pressures exerted by each material were determined after embedment, sterilization, and low temperature exposure. It is hoped that an analysis of the data may reveal a correlation between the pressure exerted on a component and the amount of variation in the electrical parameters of the component.

STATUS

All test work has been completed and the basic data obtained. These data will be analyzed and a final report issued during the first quarter of FY 69.

PUBLICATIONS

None.

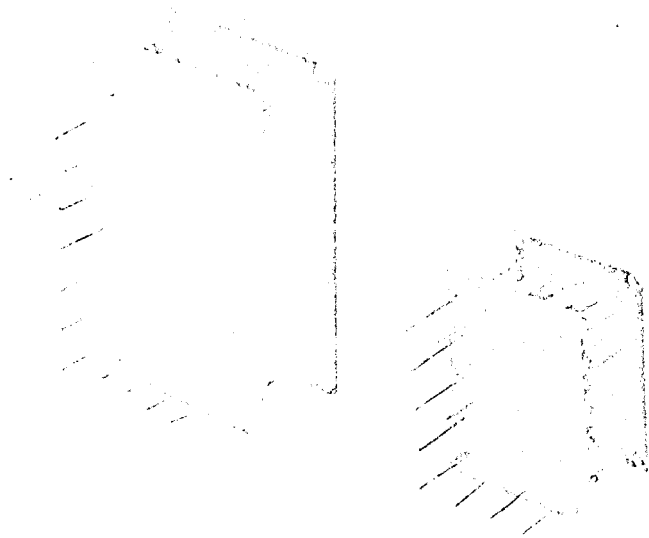


Figure 1. Unembedded Cordwood Modules

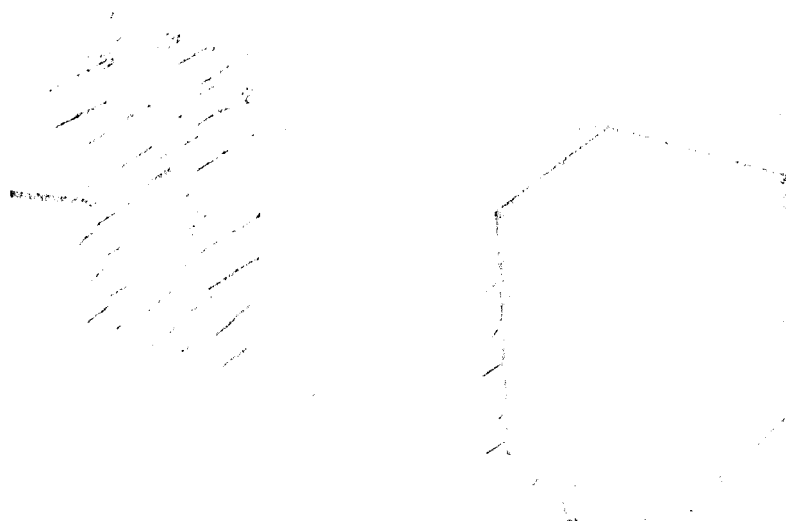


Figure 2. Embedded Cordwood Modules

STERILIZABLE CONNECTORS, WIRES, AND CABLING ACCESSORIES

NASA Work Unit 186-58-13-06-55

JPL 384-85801-2-3570

R. W. Lester

OBJECTIVE

The broad objective of this work unit was to assure the availability of sterilizable flight-type multipin electrical connectors, electrical wires, cabling accessories, and radio frequency connectors and cables. The specific objective for the past 6 mo was to verify the sterilization capabilities of assemblies of selected parts by determining whether exposure to decontamination and sterilization environments resulted in degradation of function or reliability. This work unit was closed out at the end of FY 68.

TEST SPECIMENS

The scope of test work was limited to evaluation of assemblies using parts made of materials found to be sterilizable under other NASA work units, and of designs which were thought to be compatible with sterilization and applications on future spacecraft. It is possible that parts made from sterilizable materials may not withstand sterilization environments due to mutual chemical or physical effects. For example, one concern was the finding that a tensile load of 12 oz would cause soldered hookup wires to be pulled out of solder cups, as reported in a work unit entitled "Sterilizable Soldered Connections." Then, too, critical electrical parameters of RF connectors and cables could change due to physical interactions. Candidate multipin connectors, hookup wires, and cabling accessories were tested in simulated spacecraft subsystem harness assemblies (Fig. 1). Radio frequency connectors and cables were tested as unsupported assemblies.

ACCOMPLISHMENTS

All of the planned exposure cycles, as well as electrical and physical tests of the radio frequency connectors and cables, have been completed and the portion of the planned JPL 700 Series report pertaining to these has been

written. Two cable configurations will not be recommended for use on sterilizable spacecraft because of impaired physical properties resulting from ethylene oxide decontamination. In addition, one group of RF connectors was found to be unsatisfactory because an adhesive is used which degrades at thermal sterilization temperatures, resulting in unacceptable mechanical and electrical changes. The exposures and tests of the simulated subsystem harnesses have been accomplished and the temperature sterilization cycles are 75% completed. While some polymeric materials have become discolored, no significant electrical or physical degradation of harness components has been noted. Since all ETO decontamination has been completed, closeout of the contract with Northrop Space Laboratories for this activity has been initiated.

FUTURE PLANS

Since this work unit will not be continued, the conclusion of the harness testing will be accomplished under NASA Work Unit 186-68-10-10-55, "Evaluation and Qualification of Connectors and Wires." Connectors, wires, cables, and cabling accessories which have been shown to be capable of withstanding decontamination and sterilization will be included in JPL Specification ZPP-2010-SPL, "Electronic Part Sterilization Candidates for Spacecraft Applications" with the appropriate indication that testing of these parts is complete and that they have been accepted.

ANTICIPATED PUBLICATIONS

Lane, F. L. and Lester, R. W., "Sterilization Effects on Selected Spacecraft Connectors, Wires and Cabling Accessories," JPL Informal Document, 700 Series.

PUBLICATIONS

None.

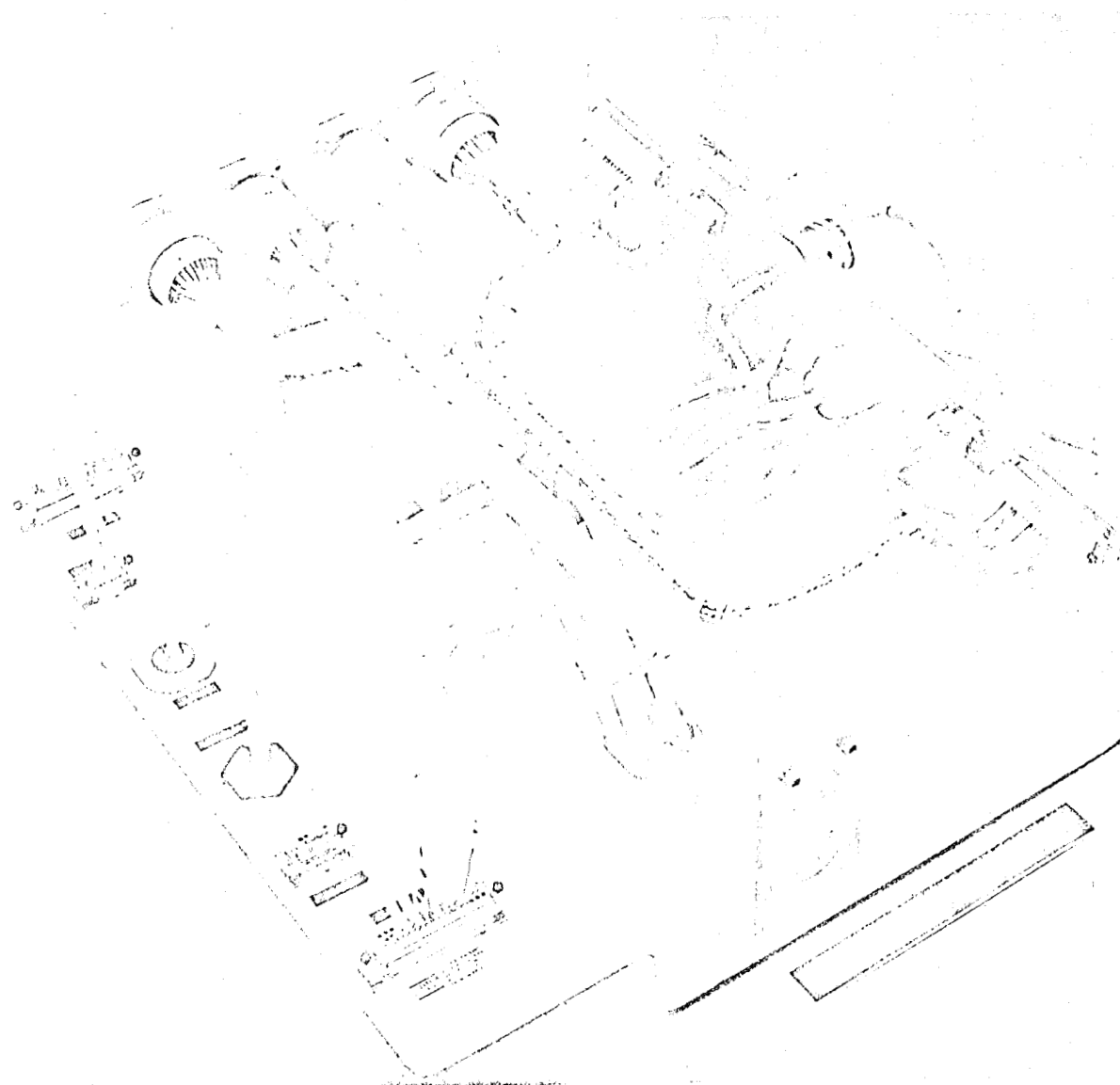


Figure 1. Typical Harness and Fixture Assembly Simulating a
Spacecraft Subsystem Interconnect Harness

MATRIX TEST OF STERILIZABLE PIECE-PARTS

NASA Work Unit 186-58-13-08-55

JPL 384-80401-2-3540

K. Martin

OBJECTIVE

The objective of this task is to support the NASA thermal sterilization policy by studying the temperature-time relationships, the effects of different numbers of temperature cycles, the effects of different rates of temperature change, and the effects of different storage periods at temperature. These relationships of the sterilization environments will be studied for their effects on the reliability of some representative electronic component piece parts during long life.

PROGRESS

ZPP-2127-GEN-A, Capacitor Matrix Test (Litton Systems) Mod. I. Test results as of completion of the matrix phase of the test program (see Table 1).

Linear regression was used to test the significance of the change (trend) of the parameters for each group during the six cycles. Groups P, M, I, E, and C are the temperature-time stresses that JPL considers equally effective for heat sterilization. The other groups have been included in the test program so that higher temperature-shorter time stresses could be evaluated for future reference.

Code 1 - Sprague 350D, 39 ufd, 35 v dc solid tantalum:

There were no catastrophic failures. The capacitance did not change significantly. Eight parts exceeded the 3% dissipation factor (DF) limit. The DF failures by groups were:

<u>Group</u>	<u>Failures</u>	<u>Group</u>	<u>Failures</u>
C	1	H	1
D	3	R	1
G	2		

Groups D and G exhibited an increasing DF trend during the six cycles. One hundred forty-four parts exceeded the 10 μ ampere leakage current limit. The failures by groups were:

<u>Group</u>	<u>Failures</u>	<u>Group</u>	<u>Failures</u>	<u>Group</u>	<u>Failures</u>
B	1	H	12	L	16
D	12	I	1	N	11
F	5	J	12	O	14
G	18	K	20	Q	2
				R	21

All groups except Group P exhibited a significantly increasing trend in leakage current during the six cycles.

Code 2 - Aerovox V423XP, 1 ufd, 200 v dc mylar:

There was one random catastrophic failure. The lead separated from the foil element. There was one capacitance failure in Group Q. All groups except Group Q exhibited a decreasing capacitance trend during the six cycles. However, the parts remained well within the 10% tolerance limit. There were no DF failures. Groups C, D, E, F, G, I, M, N, P, B, C, and H exhibited a significantly decreasing trend in DF during the six cycles. There were no insulation resistance (IR) failures. Groups J, R, and L exhibited a significantly decreasing trend in IR during the six cycles, although they remained well within tolerance.

Test results as of completion of 250 hr. of life testing:

Code 1 - Sprague 350D, 39 ufd, 35 v dc solid tantalum:

There were no catastrophic failures during the 250 hr. of life testing. None of the parts exceeded the capacitance tolerance limits. Seven of the parts exceeded the DF limits during 250 hr. of life testing. The DF failures listed by groups are:

<u>Group</u>	<u>Failures</u>	<u>Group</u>	<u>Failures</u>
B	1	J	1
D	2	K	1
G	1	R	1

All but 2 of the 144 matrix testing DC leakage failures recovered as of 250 hr of life testing. The two parts that remained out of tolerance were in Group Q. Nine parts that remained within tolerance limits during the matrix test exceeded the tolerance limits during the 250 hr of life testing. The DC leakage failures listed by groups are:

<u>Group</u>	<u>Failures</u>	<u>Group</u>	<u>Failures</u>
J	1	Q	8

Code 2 - Aerovox V423XP, 1 ufd, 200 v dc mylar:

There were no catastrophic failures during the 250 hr of life testing. None of the parts exceeded the capacitance tolerance limits. There was one DF failure in Group G, but this is not considered significant. No insulation resistance failures were noted.

Conclusions

Code 1

The capacitance of all groups has remained stable throughout the matrix test and the life test; capacitance does not appear to be a sterilization testing problem. As was expected from past testing experience, the DC leakage failures tended to recover during life testing; but failure during the life test of parts that remained within tolerance during the matrix test was not expected.

In addition, eight out of the nine failures were in Group Q. This problem will be closely followed during the test program. There were 8 DF failures during the matrix test and 7 DF failures during 250 hr of life testing. These failures are predominantly in the higher temperature groups. If this trend continues it could be a serious problem.

Code 2

There have been no significant catastrophic or parametric failures as of 250 hr of life testing. There is no measurement evidence that this type of mylar capacitor is significantly degraded from the effects of sterilization testing.

The following table ranks the recommended sterilization stress levels in an increasing order of degradation:

<u>Group</u>	<u>Temperature, °C</u>	<u>Time, hr</u>
P	105	336
M	115	132
E	135	22
I	125	53
C	145	9

It must be emphasized that the results and conclusions are based on only 250 hr of a 10,000-hr test, and consequently, they are subject to revision during the remainder of the test program.

ZPP-2127-GEN-A, Capacitor Matrix Test (Litton Systems) Mod. II. The pre-test screening (burn-in) has been completed. The matrix test has not started. Consequently, no conclusions can be formulated at this time.

Table 1. Test Matrix

25°C	105°C	115°C	125°C	135°C	145°C	160°C	Hours
^a Group A 30 parts (Typical)						Group B	3 ± 5 min
					Group C	Group D	9 ± 15 min
				Group E	Group F	Group G	22 ± 30 min
					Group H		36 ± 30 min
			Group I	Group J	Group K		53 ± 1 hr
				Group L			92 ± 1 hr
		Group M	Group N	Group O			132 ± 1 hr
	Group P	Group Q	Group R				336 ± 1 hr
^a Group A is the control group and does not receive heat cycling.							

STERILIZABLE POLYMERIC MATERIALS

NASA Work Unit 186-58-13-09-55

JPL 384-83901-2-3820

S. H. Kalfayan

OBJECTIVE

The primary objective of this task is to provide information on sterilizable polymeric materials for use in the design of planetary spacecraft which are required to meet a biological specification. The immediate objectives are to evaluate the validity of the decontamination and dry heat sterilization practices as applied to polymeric materials for potential use on planetary entry landing capsules, and to evaluate materials at various time-temperature conditions, and in presence of oxygen.

PROGRESS

Evaluation of ETO Decontamination Practices

Quantitative estimation of the decontamination chamber gases by gas chromatography (GC)

It was established that ethylene oxide (ETO) and Freon 12 could be estimated with an accuracy of $\pm 1.4\%$ using this method. Moisture content of the chamber could not be determined quantitatively by GC. Dependence on the chamber pressure to calculate the concentration of ETO was found to be unreliable because the composition of the ETO-Freon 12 mixture introduced into the chamber varied. Fractionation of the gaseous components and the rate at which the sterilant liquid mixture in the original cylinder is vaporized, were considered to be the causes for this variation.

Evaluation of moisture-sensing instruments

An extensive investigation of several types of moisture-sensing instruments, both at atmospheric conditions and at the ETO-Freon 12 decontamination conditions, was carried out. Types of sensors included: electrical

resistance (El-Tronics, Inc. Model 102), electrical impedance (Parametrics, Inc., Model 1000), cold mirror optical dew pointer (Technology-Versatronics, Model 707), manual dewpointer (Alnor, Model 7000 U) and wet-and-dry bulb psychrometer (Bendix, Model 566). The last two were not suited for use in the ETO-Freon 12 environment. The Alnor instrument was used as a reference standard and the Bendix psychrometer served as an additional reference.

Results showed that the Parametrics and the Technology-Versatronics sensors were irreversibly affected by the ETO-Freon 12 exposure. The Al_2O_3 of the Parametrics probe and the bismuth telluride semiconductor of the Technology-Versatronics probe seemed to have reacted with the ETO changing their capacitance or resistance. The El-Tronics sensor fared better than these two. Indications were that its sensitivity to measure relative humidity changed after ETO-Freon 12 exposure. Washing the sensor with distilled water helped but did not remedy the situation completely. The conclusion is that there is no moisture-sensing instrument that will adequately measure the relative humidity of the ETO-Freon 12 decontamination chamber.

Investigation of Dry Heat Sterilization Under Various Time-Temperature Conditions and in Presence of Oxygen

Six selected polymeric products were exposed to the following heat cycles after an initial ETO decontamination according to JPL VOL 50503-ETS specification for TA testing of piece parts and materials:

6 × 600 h at 105°C in N_2

6 × 40 h at 155°C in N_2

6 × 92 h at 135°C in N_2

6 × 92 h at 135°C in N_2 containing 0.45% O_2

The products were Epon 934 (epoxy adhesive), Viton 377-9 (fluoroclastomer) Stycast 1090 (epoxy encapsulant), Tedlar 30 (polyvinylfluoride film), EG 758 (epoxy-glass laminate), and Mystik 7352 (adhesive tape).

Evaluation of the test data allowed the following conclusions:

- (1) At 155°C for 6 × 40 h, the properties of most of the products were more adversely affected.
- (2) Heat resistant compounds such as EG 758 were not any more affected by exposure to higher temperatures for shorter periods, than to lower temperature for longer periods.
- (3) In general, sterilization at 105°C for 6 × 600 h resulted in lesser loss of the physical and mechanical properties of the polymeric products.
- (4) The presence of small quantities of oxygen (0.45%) did not affect the property changes significantly.
- (5) Although sterilization at higher temperatures resulted in increased loss of properties, the increase was not too pronounced.

FUTURE WORK

The work planned for FY 68 under this work unit has been completed, and a technical report has been prepared for publication. For FY 69, the task will consist of the evaluation of polymeric materials in planetary environments (high temperatures and pressures, atmosphere of CO₂).

PUBLICATIONS

SPS Contributions

1. Kalfayan, S. H., and Silver, R. H., "The Ethylene Oxide-Freon 12 Decontamination Procedure B. The Quantitative Estimation of Ethylene Oxide Concentration by Gas Chromatography," SPS 37-49, Vol. III, p. 193, Feb. 29, 1968.